vexation of spirit," is good philosophy for health and prevention of disease. Though it is hardly safe to presume that there is a relatively low blood-pressure in the wealthy indolent, the so-called nobility, nor even in the individual of leisure enfranchised by the War of the Rebellion.

A reputation for laziness would be considered as infamous slander by five of the cases herein reported. Only the one who was never known to hurry has the assurance of extreme age.

A report of most excellent health in these patients is often followed by sudden exertion or haste resulting in sudden apoplexy or death. The patients who cannot realize the wisdom of deliberation are numerous and hard to manage. For many of these there is some relaxation in books such as the story of *Napoleon Jackson,* the negro, likewise some of the works of Mark Twain, and *Adventures in Contentment and Friendship,* by Grayson. Such recommendation of books has been followed by good reports not attained by medicine.

And happy is the patient who has secured mental peace through such philosophy as Bryant has put into the last paragraph of "Thanatopsis;" but pitiable is the other patient, who, fearing the end of life and apprehensive of sudden death, is miserable to the last moment.

THE ELECTROCARDIOGRAPH AS A CLINICAL INSTRUMENT.[1]

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For the skilled cardiologist there is nothing new offered in this paper. For the practitioner who has waited to see if the electrocardiograph would prove a useful clinical instrument there may be desired information. Some five years of experimental and clinical work conducted by various investigators has afforded facts the consideration of which proves the usefulness of the instrument.

About 1856 Kölliker and Müller demonstrated that each contraction of the heart generated electric currents like any contracting muscle. These currents are minute, and it was only about 1900 that Einthoven, a Dutch physiologist, perfected a galvanometer sufficiently sensitive to record them accurately and quickly.

Briefly the electrocardiograph consists of a delicately silvered quartz or glass string 0.002 to 0.003 mm. in thickness, suspended between the poles of the galvanometer by a carrier and attached by wires to the electrodes leading from the patient. Between the patient and the instrument is a switch-board with several keys whose function is to protect the string, compensate for skin current, bring in or throw out of circuit the body, calibrate the excursion of the string, select the proper lead, etc. The delicate string is magnified by a microscope, and its shadow, vibrating with each heart-beat, is projected by an arc light through the microscope upon the slit of a camera containing a plate or a film moving at a fixed rate and at the will of the operator.

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[1] Read before the College of Physicians of Philadelphia, November 5, 1913.

We will briefly review the theory of the electrocardiograph and the electrocardiogram of the normal heart contraction that we may understand the abnormal curves:

Electrodes attached to the patient's extremities will lead off these currents to the galvanometer just as accurately as if the heart were exposed and the electrodes applied directly to that contracting viscus.

That these curves arise from the heart contractions is demonstrated by the fact that the curves obtained by the electrodes attached to the extremities, or attached to the intact chest walls immediately over auricle and ventricle, or attached to the auricle or ventricle laid bare, are all the same. Since the patient has only to lie or sit with his hands and a foot resting comfortably upon the electrodes covered with absorbent cotton, wet with a solution comfortably warm, every sufferer with cardiac disease is not only willing but anxious to lend himself for the study of his malady.

Thus on one hand we have the willing patient for direct examination, instead of drawing parallels between him and the experimental animal, and on the other hand an instrument so sensitive that every heart-beat, no matter how rapid or irregular, is recorded with mathematical precision. Certainly one of the few examples where a branch of medicine is reduced to an exact science.

We cannot as yet explain all the deflections in the electrocardiograms from a presumably normal heart. However, there are variations which are within the limits of health and still further variations which place the individual among the abnormal. It is the measurement of the direction, duration, and time relationships of the events in these curves which forms the basis of electrocardiography. The curves given as normal are the result of the examination and a comparison of a series of curves from a group of healthy individuals. In a large group of presumably normal people there is likely to be found an abnormal curve or so, and a careful examination of the individual will reveal slight abnormalities of the heart never suspected before.

The curves for any given person are constant at all times; so much so, that they have been suggested as an added means of identification of the individual. Any marked deviation from one's particular curve means a deviation in function. Given a normal curve, we can predicate that the auricular contraction began at the pacemaker (sino-auricular node) and followed the usual course through the auricle; and further, that the normal ventricular complex shows that this impulse reached the ventricles by way of the auriculoventricular bundle, its main branches and their ultimate subdivisions, for it has been demonstrated repeatedly, experimentally, and clinically, that the character of an electrocardiogram, like the curve from a contracting strip of plain muscle, depends upon the point of origin and the direction of the current in the heart.

More often all graphic methods in heart disease are most useful in differentiating the arrhythmias, but the electrocardiograph also yields definite and often unexpected information derivable by no other means in some conditions where the rhythm is *regular*. For instance, there are certain deviations in the directions of parts of the curve, representing each beat, where the rhythm is perfectly regular, that clinical experience has shown to be of bad prognostic significance. Mitral and pulmonary stenosis are cardiac abnormalities which produce clear symptoms and physical signs.

They should be, and postmorten shows that they are, accompanied by the expected right-sided ventricular hypertrophy. Such cases yield characteristic but abnormal curves. That such curves are characteristic of right-sided ventricular hypertrophy is also rendered likely from the following fact: Relative preponderance of the right ventricle is normal in the infant for the first few weeks after birth. Curves of such infants show the same characteristics referred to and keep them until the second or third month, when the child assumes the normal adult form.

The curves of left ventricle hypertrophy show deflections in exactly the opposite directions to those of the right side. We should expect to find these characteristic curves of left ventricular hypertrophy in aortic valve disease, nephritis, arterial sclerosis, and any disease with a constant high blood-pressure. As a rule we do, but they are by no means as constant where expected as are the characteristic curves on the right side.

These abnormal curves on the left side are often absent when expected and appear when not expected. Many electrocardiographic findings and clinical comparisons serve to emphasize the facts that the physical signs which aim to differentiate right- and left-sided ventricular hypertrophy are not always reliable, that increased fluid pressure within the ventricle from an incompetent valve is far from explaining all cases of hypertrophy, and that on postmortem the distribution of increased muscle tissue is not always where expected.

There are evidently factors in hypertrophy which are as yet little understood, but there seems no valid objection to adopting the suggestion of Lewis to speak of right- and left-sided preponderance where these characteristic curves occur. Furthermore, these curves when sufficient electrocardiographic and postmortem material from the same cases are collected, may help throw more light upon the subject.

We cannot repeat too often that a normal electrocardiogram means that the impulse arose in a supraventricular focus, and followed the normal pathway, the auriculoventricular bundle, throughout all its ramifications to and throughout the ventricles.

Again, the electrocardiograph alone reveals contractions which arise in a supraventricular focus, but follow an abnormal course to the ventricle, the so-called *aberrant* contractions.

For instance, if the left main branch of the auriculoventricular bundle is permanently or transiently deficient the impulse is entirely deflected to the right side of the heart, and though eventually both ventricles contract, the curves of such contractions are abnormal. They partake partly of the nature of the curves of right-sided preponderance or of stimulation near the base of the right ventricle.

If the right main division of the auriculoventricular bundle is deficient the impulse is carried to the left ventricle and the curve simulates the curves of left-sided preponderance and apical stimulation. Though these curves of aberrant contractions simulate the curves of preponderance, the two are fairly easily distinguishable by exact measurement. The only physical signs in a patient with aberrant contractions may be the presence of reduplicated first sounds and some enlargement of the heart on percussion.

The electrocardiograph alone reveals these defects of the main divisions of the bundle. Where this condition is permanent a main stem of the bundle is probably involved in a fibrotic change surrounding it. It is frequently associated with the auriculoventricular heart-block. Right bundle defect is the commonest, and it is most frequently associated with aortic disease.

It may be found that there is an anatomical reason, and the aortic valve and ring thickening may cut off the blood-supply more often to the right ventricle. This condition is of bad prognostic significance. Where temporary it suggests acute involvement of the bundle branch by toxins and bacteria. Lewis has recorded rheumatic cases when the condition cleared up as the fever subsided. Here we have definite evidence of myocardial involvement and an explanation of slight fever explained in some cases by no other means. A galvanometric examination of the functions of the cardiac muscle in rheumatic and other febrile diseases would probably often show that we frequently put patients to bed too late and allow them around too early.

A comparison of our knowledge of the cardiac arrhythmias a decade ago with the wealth of known facts is a glowing tribute to the polygraph, the electrocardiograph, and the workers with these instruments.

Irregularity of the heart's action has been shown to be a complex subject, and yet capable of being resolved into several more or less simple varieties by these instruments of precision. Moreover, the fixing of these definite clinical entities has added much to our prognostic and threapeutic knowledge of heart disease.

The cardiac irregularities are included under the following heads: auriculoventricular block, extrasystoles or premature beats, simple paroxysmal tachycardia, auricular flutter, auricular fibrillation, sinus disturbances, and alternation.

The electrocardiograph depicts with mathematical accuracy any variation in the conducting function of the auriculoventricular bundle. We know that normally the impulses causing the cardiac contractions arise in the sino-auricular node (at the junction of the superior vena cava and auricle) and travel by the auriculoventricular bundle to the ventricles in at least 0.2 second. Any increase beyond 0.2 second, in this technically named *a–c* or *P–R* interval, is abnormal, and detected with the greatest accuracy by the electrocardiograph. Frequently this increased *P–R* interval, the first step in block, is the only evidence we have that rheumatism or other infective disease has involved the myocardium. With precision the instrument pictures simple prolonged conduction, dropped beats, the varying responses of the ventricle to the auricle, complete dissociation of auricle and ventricle, and finally the exact sites at which the impulses arise which control the independently beating auricle and ventricle. The same curves not infrequently show not only heart-block but right- or left-sided hypertrophy, and premature beats with the exact location of the origin. Furthermore, the slow pulse due to true bradycardia, such as occurs after infectious diseased like influenza, and true nodal rhythm are sharply defined from block.

Premature beats, the commonest cause of intermittent pulse, are shown to be ectopic in their origin, that is, they arise at points other than the sino-auricular node. Their ventricular, auricular, or junctional origin is made clear. If ventricular, the shape of the curve shows whether they arise in right or left ventricle. If auricular, their abnormal curve reveals their ectopic focus of origin, their abnormal course through the auricle; and further, the normal ventricular response shows that the impulse followed the normal path (auriculoventricular bundle) to and throughout the ventricles. Again, if the ventricular response is abnormal to this ectopic stimulation from the auricle, it is shown to be due to deficient conduction in one of the main divisions of the bundle (aberration). Premature beats are easily recognized in electrocardiograms, but in other graphic records, especially where they occur in groups, they may simulate auricular fibrillation, heart-block, flutter, and alternation.

Simple acceleration of the pulse such as occurs in fever, hyperthyroidism, after muscular exercise and emotion, are distinguished by their normal electrocardiographic curves from simple paroxysmal tachycardia. The latter is due to an ectopic focus in the auricle catching the lead and dominating the rhythm. This focus is usually in the auricle, but occasionally in the ventricle. The electrocardiograms distinguish simple acceleration, simple paroxysmal tachycardia, and auricular flutter.

Auricular flutter, unless treated by digitalis and a higher grade of heart-block than the usual 2 to 1 produced, can rarely be diagnosed accurately except by the electrocardiograph, and that instrument alone reveals the ectopic origin of this abnormal form of heart action. Untreated, this rapid heart action tends to persist over long periods, much to the detriment of the patient with an already overtaxed heart. The good results of treatment are fully worth the trouble of an accurate diagnosis.

Auricular fibrillation demands accurate diagnosis because of its frequency and the usual brilliant results in treatment. True, it can be diagnosed often by the palpating finger, the stethoscope, or the polygraph, but slow fibrillation is easily overlooked if ordinary methods alone are used in diagnosis. The constant absence of auricular contraction variation *P*, and the presence of the oscillations due to the fibrillating auricle in the curves, the perfectly regular pulse with the auricle still fibrillating where complete block is present, the pictures of block, of aberrant ventricular responses, of ventricular extrasystoles with their different foci of origin, as in digitalis coupling, make the curves quite worth while, though the bare diagnosis of auricular fibrillation may be already made by other means. Respiratory arrhythmias and sino-auricular block are worthy of distinct separation from other irregularities not because of their clinical importance, but to allay the anxiety of the patient, and not unfrequently of the physician himself.

In alternation we have perhaps the one condition where the polygraph may give evidence not afforded by the electrocardiograph. However, on the other hand, the latter instrument sometimes shows alternation where the former fails. Recent evidence as to the grave prognostic significance of alternations makes it worthy of study.

The introduction of the phonocardiograph, by which murmurs may be registered graphically simultaneously with the electrocardiogram, should prove useful, especially in teaching the subject of heart disease. This will be more practical, since a form of electrocardiograph is appearing in which two strings may be used in the same galvanometer, one registering the heart contraction (electrocardiogram) the other the heart sounds and valvular murmurs (phonocardiogram)

In the electrocardiograph we have then an instrument which shows whether each impulse that gives rise to a cardiac contraction arises in the normal pacemaker (sino-auricular node) or elsewhere in the auricle or in the ventricle, whether the impulse pursues the normal course through the *A–V* bundle to and throughout the ventricles, or an aberrant course, and whether the rate of propagation from the auricle to the ventricle was normal or delayed. An instrument which pictures all these facts with mathematical precision must be and is more accurate than the registration of cardiac movements by means of the polygraph, which depicts alone the changes in intra-auricular, intraventricular, and intravascular pressure. However, though the electrocardiograph will be the court of last resort, the ink polygraph, because of its portability, its comparatively small cost, and the large amount of information it is capable of providing, is in no danger of being relegated to the shelf. Again, the knowledge obtained from electrocardiograms makes easier the interpretation of polygraph curves with greater accuracy, and a knowledge of the information afforded by both instruments increases the diagnostic ability of the physician by means of the palpating finger and the stethoscope alone. The different forms of cardiac irregularity have been shown to vary widely in their prognostic significance and their reaction to treatment. In the future the patient will expect, the insurance companies will often require, and the conscientious physician will not rest satisfied without a determination of the exact character of the cardiac irregularity in question.

The increased working reliability of a good electrocardiograph, the decreased price, and the known refinements in diagnosis it affords render the possession of one necessary by every hospital trying to do the best grade of work in cardiac diseases. Since the best deflections of the string are obtained in a strong magnetic field, the electrocardiograph with a *permanent* magnet must prove its worth before its greatly reduced price should be a factor in selecting an instrument.

The writer has attempted to treat the subject in a general way. Those not already familiar with it will find the whole subject technically yet simply set forth in *Clinical Electrocardiography*, by Dr. Thomas Lewis, to whom the writer wishes to express appreciation of his work and of the opportunities to participate therein in his laboratory which Dr. Lewis has afforded those interested in the subject.

A SIMPLE METHOD FOR THE INDIRECT TRANSFUSION OF BLOOD.

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The method consists of two parts: (1) obtaining blood from the donor, by means of an aspirating apparatus, and its defibrina-